WHAT IS CLAIMED IS:

1. Cardiac output measuring apparatus, comprising:

a stimulation source adapted to produce a stimulation current;

a first interface adapted to receive;

(i) first signals from a first signal source, said first signals being related at least in part to said stimulation current; and

(ii) second signals from a second signal source, said second signals being useful in the determination of cardiac output; and

a second interface adapted to at least provide output data to a monitoring device.

2. The apparatus of Claim 1, further comprising data processing apparatus, said processing apparatus being adapted to process at least a portion of said first and second signals to generate said output data.

3. The apparatus of Claim 2, wherein said data processing apparatus comprises:

at least one analog-to-digital converter adapted to convert at least said first signals from the analog domain to the digital domain;

a digital processor, operatively coupled to said at least one converter, adapted to process said digital domain signals.

4. The apparatus of Claim 3, wherein said digital processor comprises a digital signal processor (DSP) with computer program running thereon.

5. The apparatus of Claim 4, wherein said DSP comprises a pipelined processor core with arithmetic logic unit (ALU) which is optimized for at least one arithmetic operation.

6. The apparatus of Claim 4, wherein said computer program comprises a program adapted to identify at least one fiducial point within at least said first signals using a wavelet transform.

7. The apparatus of Claim 6, wherein said first signals comprise an impedance waveform, said second signals comprise ECG signals, and said computer program is adapted to identify at least one fiducial point within each of said impedance waveform and said ECG signals.

8.   The apparatus of Claim 1, wherein said second interface further comprises a network interface device adapted to facilitate transmission of said output data to said monitoring device over a data network.

9.   The apparatus of Claim 1, wherein said second interface comprises a wireless interface adapted to transmit said output data to said monitoring device over a wireless data link.

10.   The apparatus of Claim 9, wherein said second interface comprises a radio-frequency (RF) data link.

11.   The apparatus of Claim 9, wherein said second interface comprises an infra-red data link.

12.   The apparatus of Claim 9, wherein said monitoring device comprises a personal electronic device (PED) adapted to store at least a portion of said output data therein.

13.   The apparatus of Claim 3, further comprising a microprocessor, said microprocessor being configured to control at least a portion of the operation of said cardiac output measuring apparatus and said third interface.

14.   The apparatus of Claim 13, wherein said microprocessor includes a computer program adapted to generate said output data according to at least one data communication protocol.

15.   The apparatus of Claim 1, wherein said second source comprises a plurality of sources of ECG signals, and said second interface comprises apparatus adapted for selecting between said plurality of ECG signals based on at least one parameter.

16.   The apparatus of Claim 15, wherein said act of selecting comprises:

receiving a plurality of ECG waveforms at said processing device, each of said waveforms having a plurality of features associated therewith;

generating a plurality of parameters relating to said plurality of features of each of said waveforms;

generating a sum of said plurality of parameters for each of said waveforms; and

selecting one of said plurality of waveforms for further processing based at least in part on the value of said sums.

17. The apparatus of Claim 3, further comprising signal filtering apparatus adapted to filter at least a portion of said first and second signals before processing by said processing apparatus.

18. The apparatus of Claim 17, further comprising demodulator apparatus adapted to demodulate said filtered first signals prior to conversion thereof to the digital domain.

19. The apparatus of Claim 3, further comprising apparatus adapted to measure the difference in at least two of said first signals, said difference being compared to a first predetermined value to evaluate the electrical continuity of at least one of the electrical terminals associated with said first signal source.

20. The apparatus of Claim 19, wherein said apparatus adapted to measure the difference comprises a computer program running on said digital processor.

21. Cardiac output measuring apparatus, comprising:

a stimulation source adapted to produce a substantially constant stimulation current;

a first interface adapted to receive first signals from a living subject, said first signals being related at least in part to the impedance of at least a portion of the thoracic cavity of said living subject, said impedance being related at least in part to said stimulation current;

a second interface adapted to receive electrocardiographic (ECG) signals from a signal source, said ECG signals being useful in the determination of cardiac output;

at least one analog-to-digital conversion apparatus adapted to convert said first signals and said ECG signals from the analog to the digital domain;

a first digital processor operatively coupled to said at least one conversion apparatus and having a computer program running thereon, said digital processor being adapted to process at least a portion of said first signals and said ECG signals to develop an estimate of the cardiac output (CO) of said living subject;

a second digital processor adapted to control at least a portion of the operation of said cardiac output measurement apparatus; and

a third interface, operatively coupled to said second digital processor, and adapted to output at least data relating to said estimate of CO to a monitoring device.

22. A system for determining the cardiac output of a living subject, comprising:

a plurality of electrode assemblies, each electrode assembly having a plurality of terminals, at least two of said plurality of terminals being spaced from one another by a predetermined distance;

a current source capable of generating a substantially constant current;

a plurality of electrical leads connecting said current source with individual ones of said terminals of said electrode assemblies,

a first circuit adapted to measure the difference in voltage at said terminals resulting from the flow of said current through said subject and said terminals under varying cardiac conditions of said subject;

a second circuit adapted to measure ECG potentials from at least one of said electrode assemblies; and

at least one processing circuit adapted to process said voltage and ECG potentials and develop an estimate of cardiac output therefrom.

23. The system of Claim 22, further comprising a third circuit adapted to measure the difference in the impedance of at least two of said terminals as a function of time, said difference being compared to a first value to evaluate the electrical continuity of at least one of said terminals.

24. The system of Claim 22, wherein said at least one processing circuit comprises:

(i) at least one analog-to-digital converter; and

(ii) at least one digital processor in data communication with said at least one converter, said at least one digital processor having at least one computer program running thereon.

25. The system of Claim 22, wherein said second circuit comprises a circuit adapted to measure body surface potentials between at least two of said terminals in order to identify a plurality of QRS complex events within said subject.

26.   The system of Claim 25, wherein said QRS complex events are identified at least in part using a wavelet transform.

27.   The system of Claim 24, further comprising apparatus operatively coupled to said second circuit and adapted for automatic selection between a plurality of said ECG potentials based on at least one parameter.

28.   The system of Claim 22, wherein said terminals each comprise:

a central axis;

a sidewall portion substantially parallel to said axis; and

a top portion, said top portion having a diameter greater of that of said vertical sidewall portion.

29.   The system of Claim 28, wherein said electrical leads each comprise a connector, said connector being adapted to form an electrical conduction path between said connector and a respective one of said terminals, said connector further comprising a plurality of electrically conductive arms biased against said sidewall portion of said terminal when said connector is mated with said terminal.

30.   The system of Claim 22, further comprising at least one monitoring device in data communication with said at least one processing circuit, and adapted to interface therewith, for displaying information related to said estimate of cardiac output.

31.   The system of Claim 30, wherein at least one of said at least one monitoring devices is physically remote from said system, said system further comprising a data network interface in data communication with said at least one processing circuit to facilitate transmission of said information to said at least one remote monitoring device.

32.   A method of determining the cardiac output of a living subject, comprising:
generating an electrical current;

applying said electrical current to at least a portion of said living subject;

measuring an impedance waveform generated by said electrical current passing through said living subject;

obtaining a cardiographic waveform from said subject during at least a portion of said act of measuring;

converting at least a portion of said impedance and cardiographic waveforms to the digital domain;

determining stroke volume from the measured voltage; and

determining cardiac output based at least in part on said stroke volume.

33. The method of Claim 32, wherein the act of determining stroke volume comprises determining ventricular ejection time (VET) and the derivative of impedance, and calculating stroke volume based at least in part thereon.

34. The method of Claim 33, wherein the act of determining cardiac output comprises multiplying stroke volume and cardiac rate.

35. The method of Claim 32, wherein said act of determining stroke volume comprises detecting at least one fiducial point within said impedance waveform using a wavelet transform.

36. The method of Claim 32, wherein said act of obtaining comprises selecting one from a plurality of electrocardiographic (ECG) waveform inputs.

37. The method of Claim 36, wherein said act of selecting comprises:

evaluating each waveform for signal quality based upon at least one parameter;

ranking each waveform based on said act of evaluating; and

selecting said one waveform based at least in part on said ranking.

38. The method of Claim 37, wherein said act of evaluating comprises evaluating each waveform with a predetermined window of time, said window of time corresponding to at least a minimum number of cardiac beats.

39. The method of Claim 38, wherein said act of selecting further comprises utilizing a hierarchical process to select said one waveform when said ranking of two or more of said waveforms is equivalent.

40. The method of Claim 36, wherein said act of selecting comprises evaluating the signal quality of each waveform based on at least R-wave signal amplitude.

41. The method of Claim 40, wherein said R-wave signal amplitude is determined by:

identifying a first R point value;

subtracting the previous local minimum point value.

42. The method of Claim 41, further comprising:

summing the amplitudes of those R points found in a predetermined time window which includes said first R point value; and

averaging said summed amplitudes to determine a mean R wave signal amplitude.

43. The method of Claim 36, wherein said act of selecting comprises generating a plurality of parameters relating to the signal quality of said ECG waveform inputs.

44. The method of Claim 43, wherein said plurality of parameters are selected from the group comprising:

(i)   R-wave amplitude;

(ii)   QR interval difference; and

(iii) RR interval difference.

45. The method of Claim 43, further comprising:

generating a sum of said plurality of parameters for each ECG waveform input;

normalizing said sums; and

selecting the ECG input waveform with the highest value of said sum.

46. The method of Claim 36, further comprising determining cardiac rate at least in part from said one selected ECG waveform.

47. The method of Claim 32, further comprising outputting said stroke volume and/or said cardiac output determinations to a monitoring device according to a communications protocol.

48. The method of Claim 32, further comprising outputting said stroke volume and/or said cardiac output determinations via a network interface to a remote monitoring device.

49.   A method of providing an input waveform to a processing device, comprising:

receiving a plurality of input waveforms at said processing device, each of said waveforms having a plurality of features associated therewith;

generating a plurality of parameters relating to said plurality of features of each of said waveforms;

generating a sum of said plurality of parameters for each of said waveforms; and

selecting one of said plurality of waveforms for further processing within said processing device based at least in part on the value of said sums.

50.   The method of Claim 49, wherein said input waveforms comprise electrocardiograph (ECG) waveforms having at least one QRS complex, and said features are selected from the group comprising:

(i)   R-wave amplitude;

(ii)   QR interval difference; and

(iii)   RR interval difference.

51.   The method of Claim 50, wherein said act of determining R-wave amplitude comprises:

summing the amplitudes of those R points found in a predetermined time window which includes a first R point value; and

averaging said summed amplitudes to determine a mean R wave signal amplitude.

52.   The method of Claim 49, further comprising normalizing each of said sums of said plurality of parameters to a predetermined value.

53.   The method of Claim 52, wherein said act of selecting comprises:

ranking each of said normalized sums; and

selecting said one waveform for further processing based at least in part on said ranking.

54.   The method of Claim 53, wherein said act of selecting further comprises utilizing a hierarchical process to select said one waveform when said ranking of two or more of said waveforms is equivalent.

55.	A method of processing an input waveform in a cardiac output determination apparatus, comprising:

receiving a plurality of input waveforms at said apparatus, each of said waveforms having a plurality of fiducial points associated therewith;

5	identifying said fiducial points;

generating a plurality of parameters relating to said plurality of fiducial points of each of said waveforms;

generating a sum of said plurality of parameters for each of said waveforms;

selecting one of said plurality of waveforms for further processing within said

10	processing device based at least in part on the value of said sums; and

processing said one selected waveform in conjunction with an impedance waveform to determine cardiac output.

56.	The method of Claim 55, wherein said act of identifying comprises utilizing a wavelet transform to detect at least one of said fiducial points in each of said

15	waveforms.

57.	The method of Claim 55, further comprising converting each of said waveforms to the digital domain for said processing.

58.	Cardiac output measuring apparatus, comprising:

stimulation means adapted to produce a stimulation current;

20	first interface means adapted for receiving first signals from a first signal source, said first signals being related at least in part to said stimulation current;

second interface means adapted for receiving second signals from a second signal source, said second signals being useful in the determination of cardiac output;

third interface means adapted for at least providing output data to a monitoring

25	device; and

digital processor means operatively coupled to said first and second interface means for processing said first and second signals to determine cardiac output.

59.	Cardiac output measuring apparatus, comprising:

stimulation means adapted to produce a stimulation current;

30	first interface means adapted to receive;

(i)   first signals from a first signal source means, said first signals being related at least in part to said stimulation current; and

(ii)   second signals from a second signal source means, said second signals being useful in the determination of cardiac output; and

second interface means adapted to at least provide output data to a monitoring device.

60.   Yoke apparatus adapted to measure cardiac output in a living subject, comprising:

a stimulation source adapted to produce a stimulation current;

a first interface adapted to receive;

(i)   first signals from at least one electrodes, said first signals being related to the thoracic impedance of said subject resulting from the application of said stimulation current thereto; and

(ii)   second signals from at least one electrode, said second signals being related to the ECG of said subject; and

a second interface adapted to at least provide output data to a monitoring device;

wherein said yoke apparatus is adapted to be physically separable from said monitoring device.

61.   The yoke apparatus of Claim 60, further comprising:

at least one analog-to-digital converter, said at least one converter adapted to convert said first and second signals to the digital domain for processing; and

at least one digital processor in data communication with said at least one converter, said at least one processor having at least one computer program running thereon, said at least one computer program being adapted to determine at least ventricular ejection time (VET) from said first and second signals.

62.   The yoke apparatus of Claim 61, wherein said at least one computer program is further adapted to detect a plurality of fiducial points with at least said first signals.

63.   The yoke apparatus of Claim 62, wherein said detection of said fiducial points is accomplished using discrete wavelet transforms.

64.   The yoke apparatus of Claim 60, wherein said second interface comprises a wireless interface adapted to transfer a plurality of data bytes between said yoke and said monitoring device.

65.   The yoke apparatus of Claim 61, wherein said wireless interface comprises a Wireless Medical Telemetry Service compliant radio frequency (RF) interface.

66.   The yoke apparatus of Claim 60, wherein said second interface comprises a LAN network card adapted to transfer data between said yoke and at least one remote network node.

67.   The yoke apparatus of Claim 60, wherein said second interface is adapted to transmit said output data as a plurality of data packets.

68.   The yoke apparatus of Claim 60, wherein said second interface further comprises at least one power terminal adapted to receive electrical power from said monitoring device.

69.   The yoke apparatus of Claim 60, further comprising an outer housing, said outer housing adapted to receive at least one other electronic module therein.

70.   The yoke apparatus of Claim 61, wherein said outer housing is of molded construction, and said second interface comprises a multi-pin electrical connector.

71.   The yoke apparatus of Claim 60, further comprising apparatus of automatically selecting from a plurality of said second signals received by said yoke based upon the quality of each of said plurality of second signals.

72.   The yoke apparatus of Claim 61, further comprising apparatus of automatically selecting from a plurality of said second signals received by said yoke based upon the quality of each of said plurality of second signals.

73.   The yoke apparatus of Claim 63, further comprising apparatus of automatically selecting from a plurality of said second signals received by said yoke based upon the quality of each of said plurality of second signals.

The yoke apparatus of Claim 60, wherein said second interface comprises a universal serial bus (USB) interface.

74.   The yoke apparatus of Claim 60, further comprising a microprocessor and data storage device, said microprocessor, data storage device, and said at least one digital

processor being in data communication, said microprocessor at least controlling the transfer of data between said yoke apparatus and said monitoring device via said second interface.

75.   The yoke apparatus of Claim 60, wherein said first interface comprises a wireless data interface.

76.   The yoke apparatus of Claim 61, wherein said first interface comprises a wireless data interface.

77.   The yoke apparatus of Claim 60, further comprising a third interface, said third interface being adapted to receive data from a processing device, said processing device being adapted to determine at least one physical parameter of said subject .

78.   The yoke apparatus of Claim 60, further comprising a third interface, said third interface being adapted to transfer cardiac data to a processing device, said processing device being adapted to determine at least one physical parameter.

79.   The yoke apparatus of Claim 76, wherein said cardiac data comprises cardiac output (CO) data.

80.   Cardiac measuring apparatus, comprising:

a stimulation source adapted to produce a stimulation current;

a first interface adapted to receive;

(i)   first signals from a first signal source, said first signals being related at least in part to the thoracic impedance of a living subject, said impedance being related at least in part to said stimulation current;

(ii)   ECG signals; and

(iii)   blood pressure signals received from a dialysis system; and

a second interface adapted to at least provide output data to a monitoring device.

81.   The apparatus of Claim 80, wherein said dialysis system and said cardiac measuring apparatus are substantially co-located and adapted to operate contemporaneously.

82.   The apparatus of Claim 80, wherein said monitoring device is in data communication with said dialysis system and said cardiac measuring apparatus, such that

data from both the dialysis unit and cardiac measuring apparatus may be monitored using said monitoring device.

83.   Cardiac output measuring apparatus, comprising:

a first interface adapted to receive:

5   (i) first signals, said first signals being related at least in part to the thoracic impedance of a living subject; and

(ii) a plurality of second signals, said second signals being useful in the determination of cardiac output;

apparatus adapted to select one of said plurality of second signals based at least in

10   part on the quality of said signals;

at least one analog-to-digital converter adapted to convert at least a portion of said first and second signals to the digital domain;

a digital processor operatively coupled to said at least one converter and adapted to determine cardiac output based at least in part on said first signals and said selected one of

15   said second signals and generate data relating thereto; and

a second interface adapted to at least provide said cardiac output data to a monitoring device.

84.   The apparatus of Claim 83, further comprising a software architecture having at least first, second, and third software modules adapted to boot the apparatus,

20   control the communication of data via said second interface, and control the operation of said digital processor, respectively.

85.   A data storage device adapted for use with a digital computer, said storage device comprising a storage medium, said medium having a plurality of data stored thereon, said plurality of data comprising a computer program, said computer program

25   being adapted to providing an input waveform to a processing device according to the method comprising:

recognizing a plurality of input waveforms at said processing device, each of said waveforms having a plurality of features associated therewith;

generating a plurality of parameters relating to said plurality of features of each of

30   said waveforms;

generating a sum of said plurality of parameters for each of said waveforms; and

selecting one of said plurality of waveforms for further processing within said

processing device based at least in part on the value of said sums.

86.   The storage device of Claim 85, wherein said computer program is further

adapted to process said one selected waveform in conjunction with at least one impedance

waveform to determine cardiac output.